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LONG-TERM SPECTROSCOPIC VARIABILITY OF TWO Oe STARS

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The Oe spectral category was first introduced by Conti & Leep (1974) to classify those O-stars exhibiting emission in the hydrogen Balmer lines, but not in He II λ 4686 nor N III $\lambda\lambda$ 4634-40. These objects are quite rare (see e.g. Negueruela et al., 2004) and most of them have not been studied in detail. Oe stars have rather large rotational velocities and their emission lines frequently display a double-peaked morphology. As for Be stars, these emission lines are interpreted as the signature of a circumstellar disk of matter expelled by the star. Oe stars are thus believed to represent the earliest representatives of the Be phenomenon. Indeed, Negueruela et al. (2004) argued that many Oe stars had previously been classified too early because of the infilling of He I classification lines.

In this paper, we present the results of a spectroscopic monitoring of HD 45314 and HD 60848, which have been reclassified as B0 IVe and O9.5 IVe respectively by Negueruela et al. (2004). Spectra of these stars were collected with the Aurélie spectrograph at the 1.52-m telescope of the Observatoire de Haute Provence (OHP, France) and echelle spectra were taken with the FEROS instrument at the 1.5 and 2.2-m telescopes at La Silla (ESO, Chile; see Table 1). All the data were reduced with the MIDAS software developed at ESO and with private routines designed for the specific reduction of Aurélie and FEROS data. Special attention was paid to ensure a homogeneous normalisation of the spectra.

Table 1. Journal of the observations of HD 45314 and HD 60848

Epoch	Instrument	Resolving power	Wavelength range	Number of spectra	
				HD 45314	HD 60848
Feb. 1997	Aurélie	20000	6510–6710 Å	11	6
Nov. 1998	Aurélie	30000	6500–6620 Å	7	6
Nov. 1998	Aurélie	30000	4795–4925 Å	1	1
May 1999	FEROS	48000	3900–7100 Å	10	10
May 2000	FEROS	48000	3900–7100 Å	4	6
Sep. 2000	Aurélie	10000	4460–4900 Å	3	2
May 2001	FEROS	48000	3900–7100 Å	3	3
Sep. 2001	Aurélie	10000	6350–6770 Å	3	-
Sep. 2001	Aurélie	10000	4460–4900 Å	1	-
Mar. 2002	FEROS	48000	3900–7100 Å	3	3

In addition to the strong hydrogen Balmer emission lines (mainly Hγ, Hβ and Hα), the optical spectrum of HD 45314 displays double-peaked emission in many Fe II lines (e.g. $\lambda\lambda$ 5169, 5198, 5235, 5275, 5319, 5363, 6318, 6346, 6370, 6384...) as well as some He I lines ($\lambda\lambda$ 5876, 6678, 7065 being the strongest ones). We further note the existence of weak (but definite) He II absorption lines at $\lambda\lambda$ 4200, 4542, 4686 and 5412, but also some lines of C III, N III and Si IV. These features are broadly consistent with an O9.5-B0 spectral type. We note that Fremat et al. (2006) inferred $T_{\rm eff} = 31092 \pm 557$ K and $\log g = 3.97 \pm 0.05$ for HD 45314 which corresponds to an O9.5 V spectral type, but does not rule out a B0 classification.

The spectrum of HD 60848 is dominated by emissions in Hα, Hβ, He I $\lambda\lambda$ 5876, 6678 and 7072. During some campaigns, the emission lines (with the exception of Hα) appear shell-like with a strong central absorption that reaches below the continuum level. There are a number of strong absorption lines, including amongst others He I λ 4471 and He II $\lambda\lambda$ 4200, 4542, 4686 and 5412, as well as lines of C III, C IV, N III, O II, O III, Si III and Si IV. There is no indication of Fe II emissions with a strength comparable to those seen in the spectrum of HD 45314.

We have analysed the variability of the various spectral features using the tools described by Rauw et al. (2001). All emission lines were found to display significant variations. Here, we focus on the changes seen in the hydrogen Balmer lines (see Figs. 1, 2) as well as the Fe II lines.

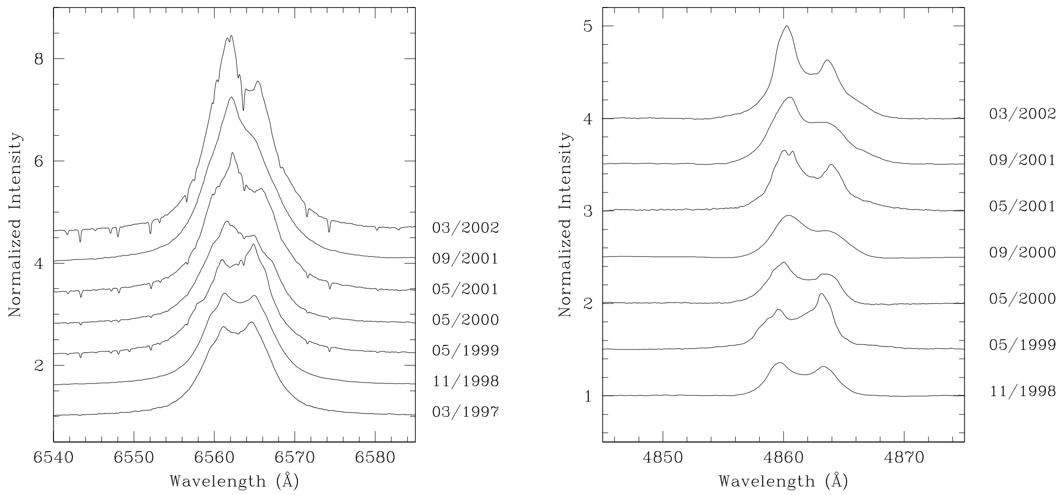

Figure 1. Line profile variations of the Hα and Hβ emission lines of HD 45314

HD 45314 presents important variations of the strengths of its emission features: the equivalent width (EW) of the Hα emission increased from ~ -20 to ~ -35 Å between 1997 and 2002 (Fig. 3). During our campaign, the Hα emission was hence much stronger than the EWs of -7.4 and -4.7 Å reported by Andrillat et al. (1982) and Andrillat (1983) from observations obtained in February 1981 and October 1981 respectively. The EW variations obviously occur on time scales of more than five years and our data do not allow to detect any periodicity. Simultaneously, we note prominent variations of the V/R ratio (see Fig. 3). Significant variations of this ratio sometimes occur over the typical duration of our observing campaigns (see the top panels of Fig. 3) tentatively suggesting a time scale of order a few months. The V/R variations of the Hβ line are less clear cut, though they qualitatively agree with the trends seen in Hα. We have also measured the radial velocity of the He II λ 4686 absorption line. On average, we obtain

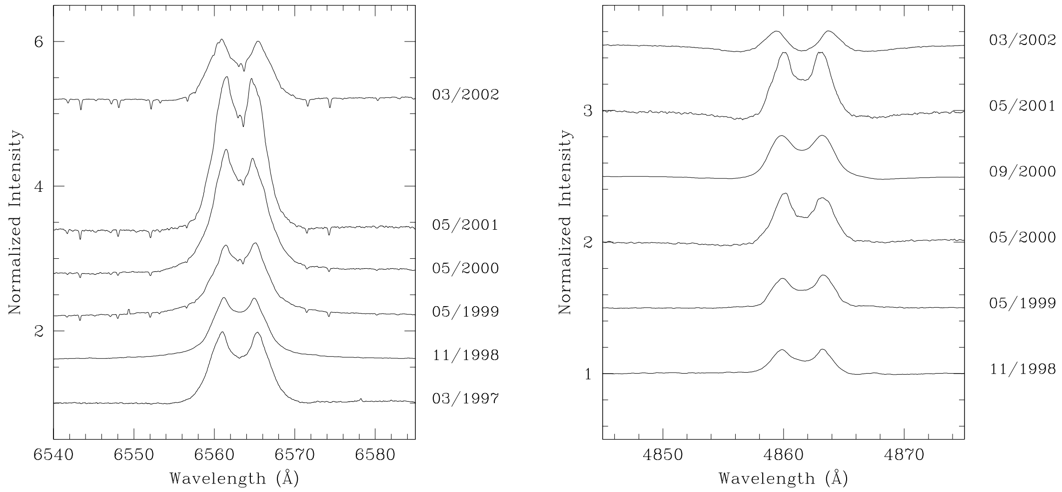

Figure 2. Same as Fig. 1 but for the Hα and Hβ emission lines of HD 60848

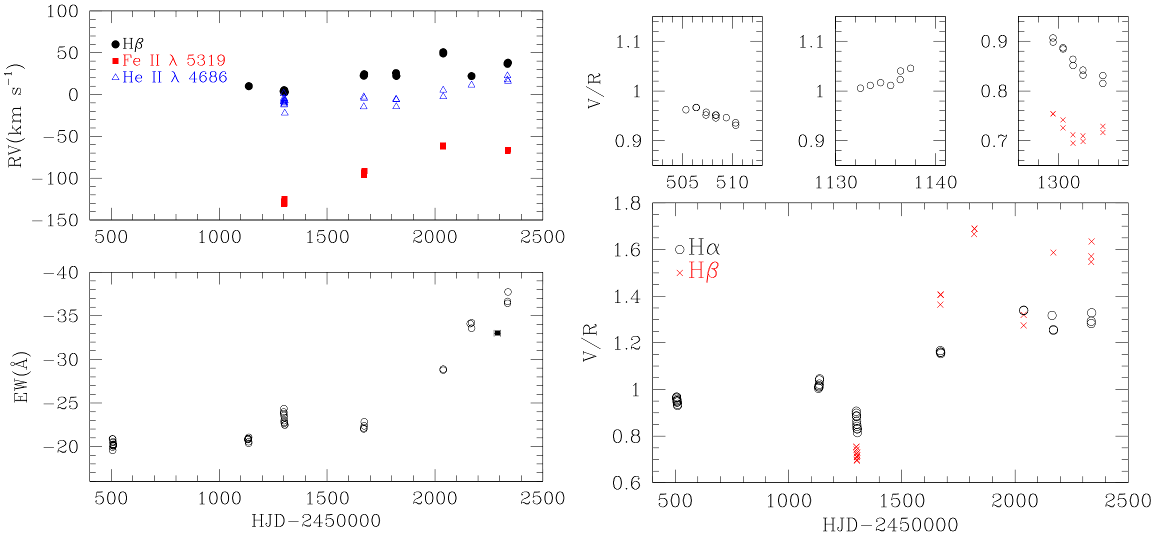

Figure 3. Variations of the spectral characteristics of HD 45314. *Left, top panel*: radial velocities of the He II λ4686 absorption and average of the RVs of the violet and red peaks of the Hβ and Fe II λ5319 emissions. *Left, bottom panel*: equivalent width of the Hα line as a function of time as measured on our spectra. The filled square corresponds to the January 2002 measurement of Negueruela et al. (2004). *Right*: $V/R = (I_V - I_c)/(I_R - I_c)$ ratio (where I_V and I_R are the intensities of the violet and red peaks respectively and I_c is the intensity of the continuum) of the Hα and Hβ lines. The top panels zoom in on those campaigns where significant trends were observed

$-2.9 \pm 11.2\,\mathrm{km\,s^{-1}}$ with the RV increasing progressively from a minimum of -22.1 to a maximum of $+22.3\,\mathrm{km\,s^{-1}}$ between May 1999 and March 2002. The violet and red peaks of the Hβ and Fe II emissions also shift in RV with time, although it is not fully clear whether these RV variations are correlated with those of the absorption line (see Fig. 3).

HD 60848 also displays strong variations of the strengths of its emission features. The EW of the Hα emission varies between ~ -5.5 and ~ -14.5 Å, with a maximum occurring between May 2000 and May 2001 (Fig. 4). The EW apparently increased at a rather slow rate between 1998 and 2001 and subsequently decreased dramatically back to its initial level in 2002. It is interesting to note that a similar decrease in the Hα EW from about -17 to -7 Å was observed between early 1981 and early 1983 (Divan et al. 1983, Andrillat et al. 1982). This suggests that the EW variations might be cyclic with a recurrence time of order five years. Contrary to HD 45314, the V/R ratio remains close to unity and displays no large variations (see Fig. 4). The radial velocity of the He II λ 4686 absorption line is found to be $22.7 \pm 6.2\,\mathrm{km\,s^{-1}}$ on average with a minimum of $+13.1$ and a maximum of $+41.3\,\mathrm{km\,s^{-1}}$ with no clear trend during our campaign.

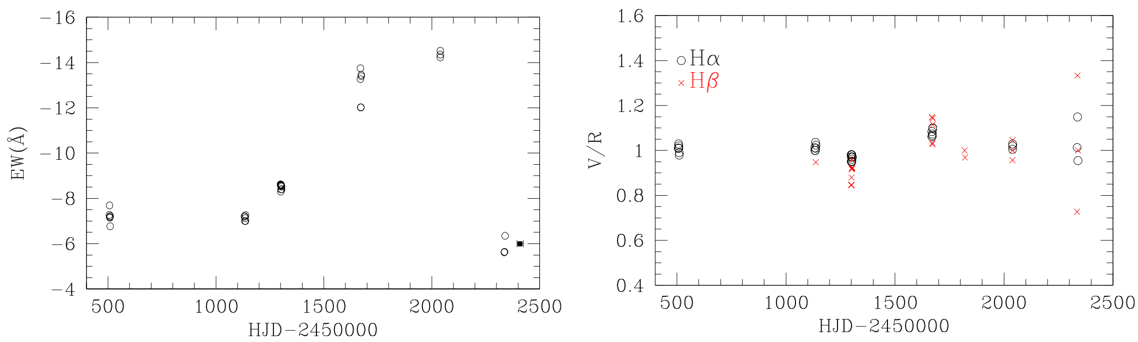

Figure 4. Variations of the spectral characteristics of HD 60848. *Left:* equivalent width of the Hα line as a function of time. The filled square corresponds to the May 2002 measurement of Negueruela et al. (2004). *Right:* V/R ratio of the Hα and Hβ lines

In summary, HD 45314 and HD 60848 both display strong long-term spectroscopic variations. Part of these variations could be recurrent. Monitoring these stars over several months and/or several years could help to specify the origin of the Oe phenomenon.

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